DRAFT 7/2/04- A Pollution Prevention Project Report to:

The United State Environmental Protection Agency
EPA Region 2
290 Broadway
New York, NY 10007-1866

On the topic of

Recycling of Two-Stroke Marine Engines

By

Thomas J. Nosker
Jennifer K. Lynch

Partners: Marine Trades Association of New Jersey

Key Project Information

The main project goals were to develop an understanding of the raw materials that could arise from a two-stroke marine engine recycling program, in an effort to replace two-stroke marine engines with more environmentally friendly four-stroke engines, as well as to identify recycling opportunities that either exist already or that could be easily developed for these materials. The project addressed Region 2 priorities: [1] promoting environmental purchasing and [2] reducing the incidence of chemicals of national concern. The underlying premise is that if there is significant value from a recyclable materials standpoint in older, two stroke marine engines then it may be possible to accelerate the retirement of these engines through some type of trade-in program which does not exist at this time.

Recycling of Two-Stroke Marine Engines

Background

The EPA targeted two-stroke marine engines as engines that produce more pollution than four-stroke engines. Consequently, the EPA was interested in the replacement of these engines with four-stroke engines as quickly as possible in order to have the maximum environmental benefit. The goals of the proposed research project were to

1. Perform general characterization of the metals and plastics derived from two-stroke marine engines
2. Identify the best practices for dismantling the engines
3. Process samples of the thermoplastic materials that are found in the highest percentages to determine the feasibility of incorporating these materials into new products or new and more efficient marine engines
4. Investigate various rebate/turn in programs to develop and outline for a system to be applied to two-stroke marine engines

The research team obtained a representative sample of recovered engines from a variety of the largest marine engine manufacturers, dismantled the engines, and determined the materials content. The two-stroke engines collected for the study were Johnson 6, Johnson 9.9, Yamaha 55, Mercury 50, and Mercury Force 70 and they appear in Figures 1 – 4, respectively. Engines were donated to the project by members of the Marine Trades Association of New Jersey. The engines covered a range of sizes and were produced over a span covering decades.

Figure 1: Johnson 6 two-stroke marine engine

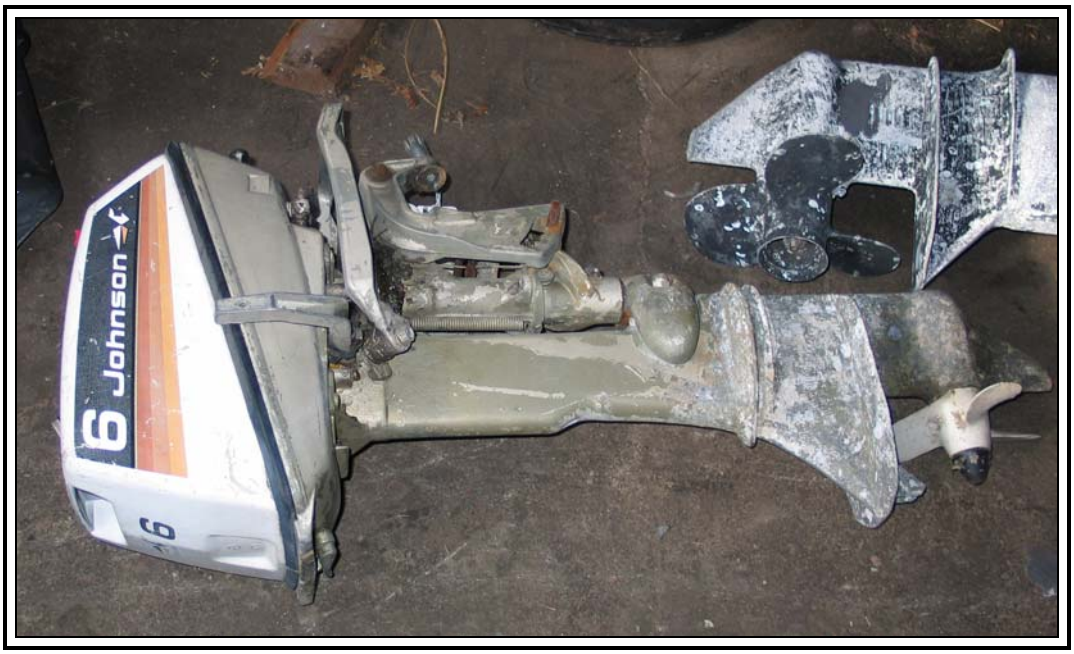


Figure 2: Johnson 9.9 two-stroke marine engine

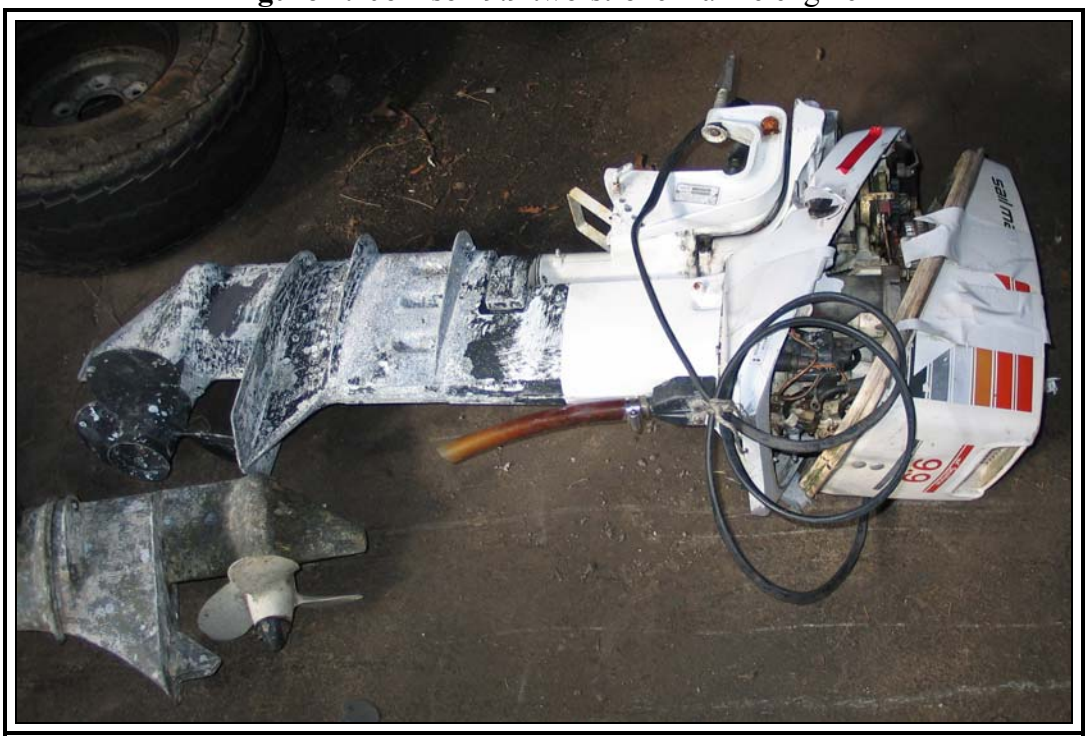


Figure 3: Yamaha 55 two-stroke marine engine

Figure 4: Mercury 50 two-stroke marine engine

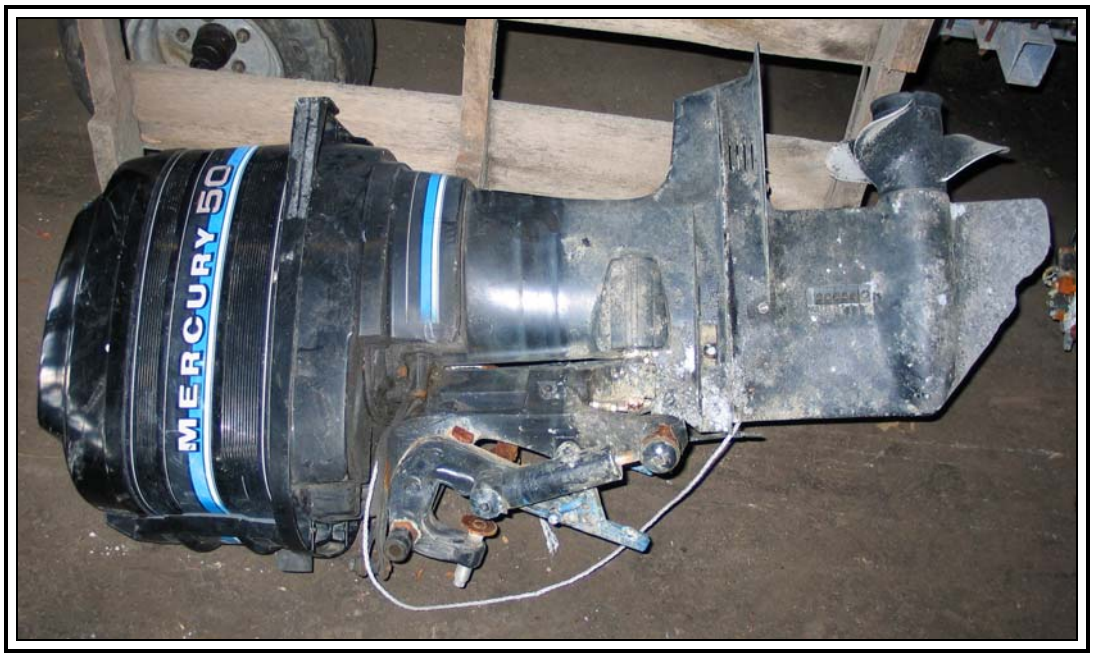


Figure 5: Mercury Force 70 two-stroke marine engine

Results

Each two-stroke marine engine was mounted and dismantled by hand. The recovered materials were separated by type and weighed for each engine. In dismantling the two-stroke marine engines, it was discovered that all of the engines have an aluminum frame, aluminum engine block, steel crankshafts and power output shafts, copper for wiring, and a small quantity of plastic.

The scale used to weigh the various recovered materials appears in Figure 6, an engine mounted for dismantling appears in Figure 7, researchers dismantling an engine appears in Figure 8, a dismantled motor appears in Figure 9, recovered aluminum from the Johnson 9.9 two-stroke marine engine appears in Figure 10, and recovered copper appears in Figure 11.

Figure 6: Weighing scale

Figure 7: A two-stroke marine engine mounted for dismantling

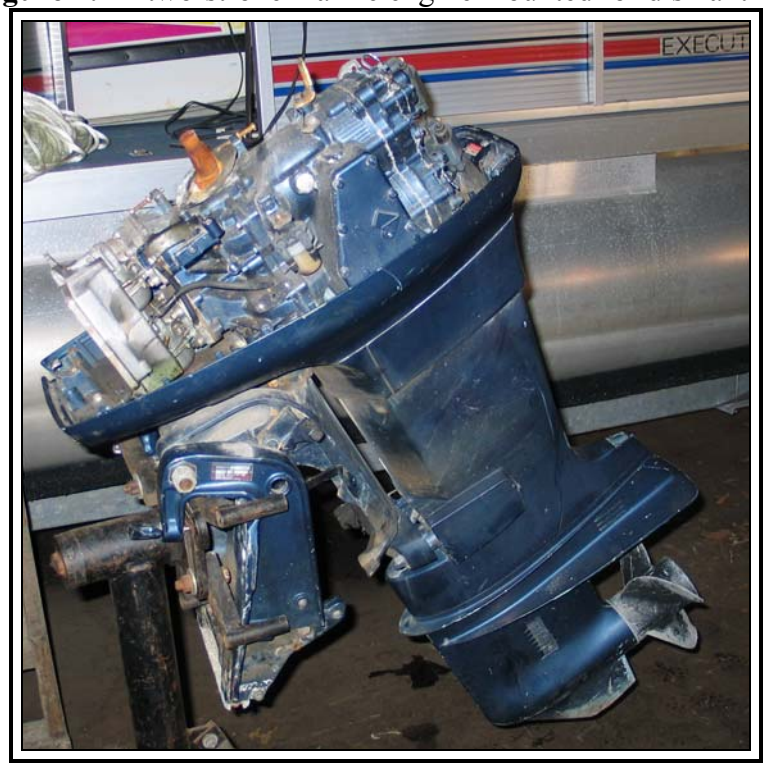


Figure 8: Researchers dismantling a two-stroke marine engine.

Figure 9: A dismantled two-stroke marine engine motor

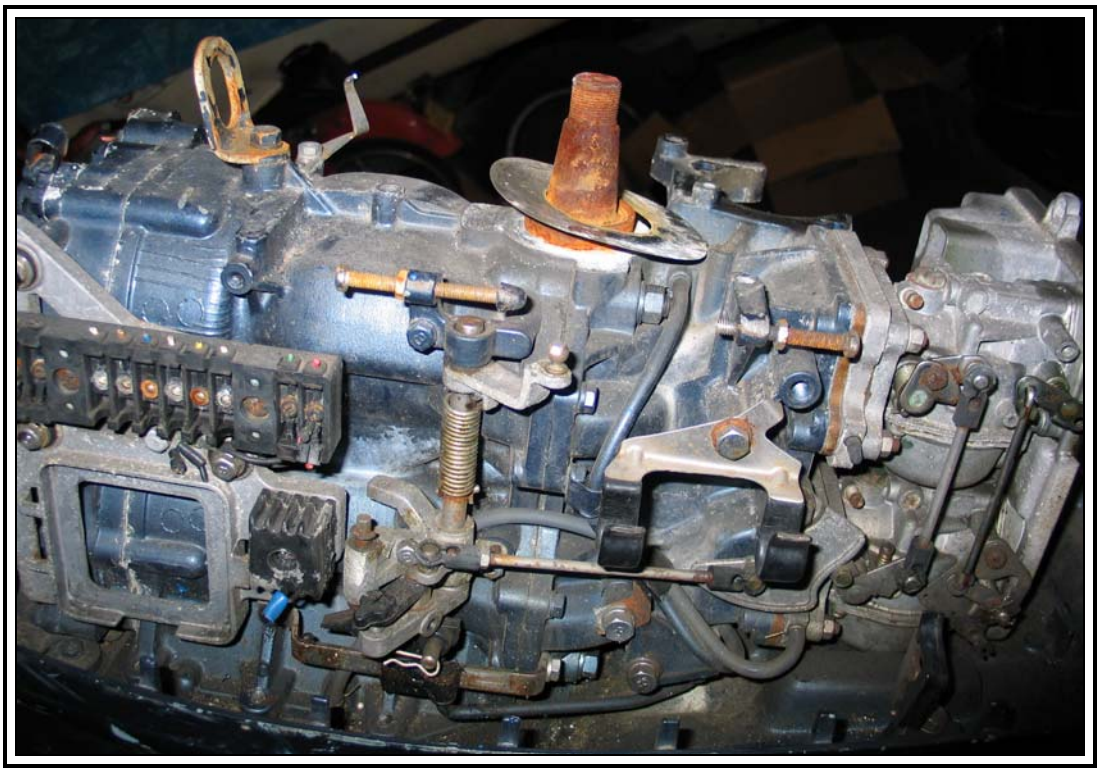
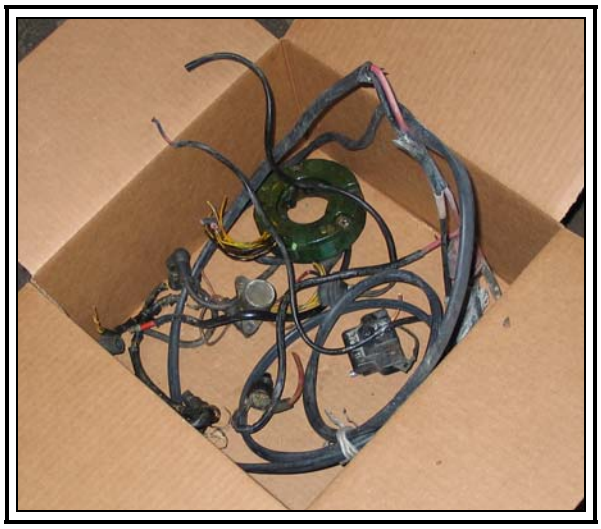


Figure 10: Recovered aluminum from the Johnson 9.9 two-stroke marine engine

Figure 11: Recovered copper



The materials recovered from the two-stroke marine engines are categorized by stainless steel, aluminum, copper, and plastic. The resulting total percentages of each material appear in Figure 12. Differences were observed in the construction and materials of the engines, according to the age of the engines. The older engine, the Mercury 50, has an aluminum hood, while the newer Johnson 9.9 and Mercury Force 70 have plastic hoods. The Mercury 50 most likely dates from the late 1960s while the Mercury Force 70 is most likely less than 5 years old.

The recovered plastics were characterized using a Perkin Elmer Fourier Transform Infrared Spectrometer with photoacoutstic detector and a TA Q1000 Differential Scanning Calorimeter. Results show that the older Johnson 9.9 hood is composed of Sheet Molding Compound (SMC), made of some polyethylene, and a variety of fillers while the newer Mercury Force 70 hood is composed of a thermoset polymer with a high percentage of fiberglass. These types of plastics are not recyclable. The remaining plastics are nylon and rubber with trace amounts of PVC and PP. The percentage of each type of plastic within the total plastics (3.8 % of the total engine weight) is shown in Figure 13. There is little opportunity or value in the plastic portion of marine engines.

Figure 12: Percentages of recovered materials from two-stroke marine engines

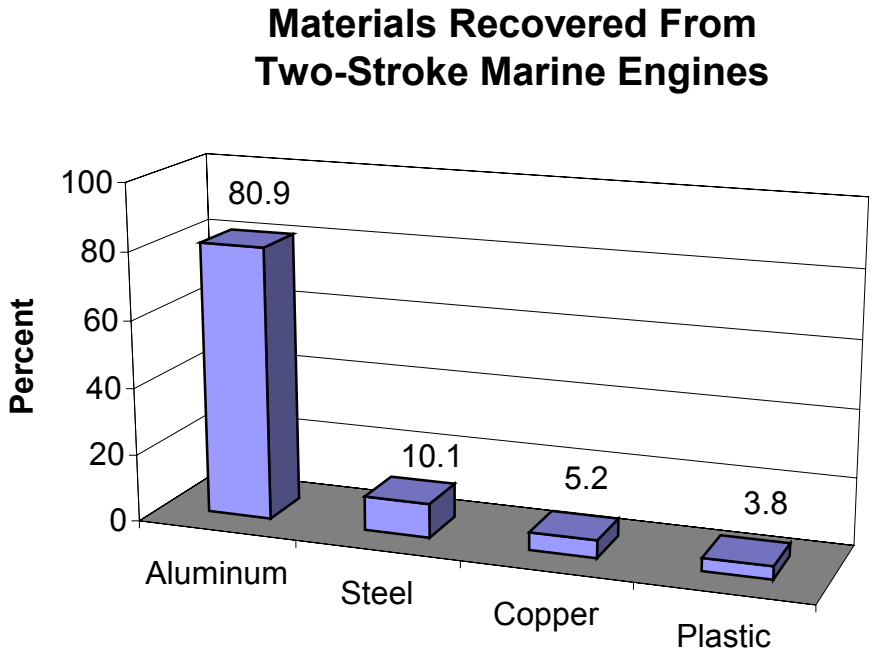
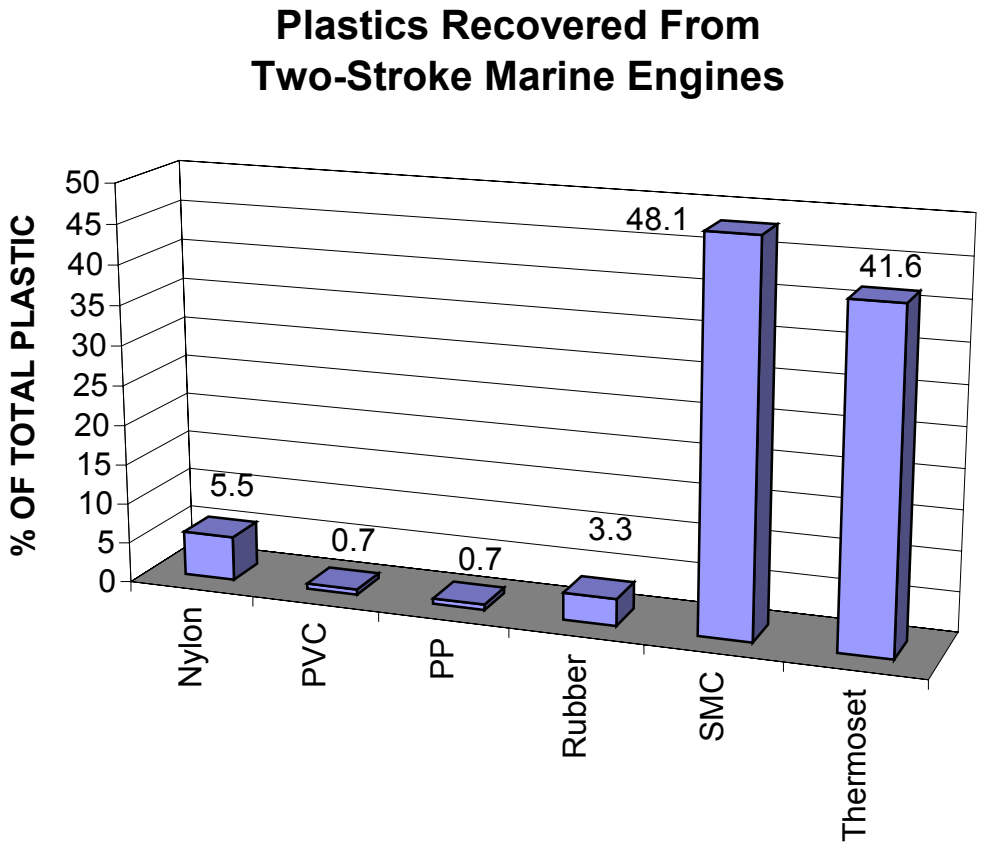


Figure 13: Percentages of each type of plastic within the total plastics recovered from two-stroke marine engines



Conclusions and Recommendations

Results indicate that two-stroke marine engines are composed primarily of aluminum (80 % of the total engine weight), and recycling these engines to recover aluminum could prove to be economical. The plastics content is low (3.8 % of the total engine weight), and thermosets and sheet molding compound are in the largest quantities. Thus, there are insufficient thermoplastics used in the manufacturing of the two-stroke marine engine for recycling and feasibility of incorporating these materials into new products.

Dismantling the engines using wrenches and screwdrivers is not efficient. The best practice for dismantling two-stroke marine engines would be to send the engines to an auto shredder company. There, the engines are granulated and separated into metal types by use of a magnet. Aluminum is separated by eddy current separation. Thus, the aluminum and steel, the materials present in the largest amounts, would be recoverable. Aluminum is currently worth about $0.40 per pound in form ready for melting. Steel is currently in short supply and worth about $0.20 per pound. A rebate or turn in program is a legitimate solution to offer consumers in order to recover the engines, and could perhaps pay for the collection of the engines and have a margin that could be offered to the owners or repair shops as incentive to take the two stroke engines out of circulation and lower their environmental impact.